MARCH 1979

EQUIPMENT DEVELOPMENT AND TEST REPORT 7700-13

Mobile Hammermill for Inplace Processing of Oversize Rock

FOREST SERVICE • U.S. DEPARTMENT OF AGRICULTURE • SAN DIMAS EQUIPMENT DEVELOPMENT CENTER

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THIS REPORT ON ED&T PROJECT NO. 2055–MAINTENANCE SYSTEMS FOR TREATMENT OF OVERSIZED ROCK–WAS SPONSORED BY ENGINEERING, FOREST ROADS AND TRAILS.

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MOBILE HAMMERMILL FOR INPLACE PROCESSING OF OVERSIZE ROCK

by

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MARCH 1979

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ABSTRACT

Forest roads with a running surface of soil or gravel often become littered with loose rock from sloughing cutbanks. Also, wearing of the road surface can expose embedded rocks. The oversize rock (i.e., those greater than 3 in, or 75 mm) on these roads have to be dealt with because they are a hazard to vehicles and create road maintenance problems. Leaving oversize rock along the side of the road, pushing them off the road and over the bank, or hauling them away can present environmental and economic problems. Thus, San Dimas Equipment Development Center (SDEDC) engineers were presented with the challenge of determining an effective and efficient method of reducing oversize material that clutters the many miles of Forest Service low-volume roads.

One solution to these problems was achieved by using a Pettibone Texas Corporation model P-500 mobile hammermill for the inplace processing of oversize rock. For many Forest Service roads, where considerable oversize material is present, the P-500 hammermill can provide a cost-effective method of reducing the unwanted, oversize material into a useful wearing course. In addition, the P-500 could be used in new construction activities where excavated, oversize rock would be reduced in place to provide a base course.

KEYWORDS: Road maintenance, oversize rock, inplace rock processing, rock reduction, (mobile) hammermill.

INTRODUCTION

One of the biggest problems facing maintenance personnel today is the presence of oversize rock material on Forest Service roadways. Most of the oversize material accumulates from cutbank sloughing, especially in mountainous areas (fig. 1). Oversize

Figure 1. Roadway accumulation of oversize material from sloughing cutbank.

material also becomes exposed in roadways due to surface erosion from traffic and runoff of surface water (fig. 2). This material, if not removed from the roadways and adjoining ditches, hinders road maintenance and presents a safety hazard to traffic. Also embedded oversize material damages motor graders and breaks cutting edges. Since the oversize rock material should not be removed by simply sidecasting it—because of the adverse environmental and esthetic impact—loading and hauling this material to disposal areas causes a considerable financial burden.

An ED&T project was assigned to the San Dimas Equipment Development Center (SDEDC) to find a cost-effective solution to the inplace reduction of oversize rock. The early stages of this project consisted of investigating and analyzing possible alternatives and their cost. [1/] The alternatives were

Figure 2. Oversize rock embedded in Forest Service roadway.

(1) removal and disposal of the material, (2) provide overlays with pit-run material, (3) use mobile jaw rock crusher, and (4) use a mobile hammermill. This report presents an evaluation of the mobile hammermill approach. Prior to selecting any method to reduce oversize rock, an analysis should be made that considers the individual situation, the overall suitability, the long-range costs, etc. of each alternative.

MOBILE HAMMERMILL

To evaluate the cost effectiveness of the most promising approach to the inplace reduction of oversize material, a Pettibone Texas Corporation's model P-500 mobile hammermill was purchased in 1975. The P-500 (fig. 3) is a self-contained, diesel-powered pulverizing hammermill that is towed by a crawler

Figure 3. The P-500 mobile hammermill.

[1/] 1974. Treatment of oversized rock on nonsurfaced roads. Proj. Rcd. USDA For. Serv., Eqpt. Dev. Ctr., San Dimas, Calif.

tractor or a similar piece of equipment. Twenty-four hammers, each weighing 57 lb (125.7 kg), provide the pulverizing action. They are attached to a rotor, which turns at 1,000 rpm, with four high-strength pins. The impact from the hammers shatters the oversize material as the hammermill is towed over the prepared windrow.

The biggest operating cost of the P-500 is the hammers, which presently require changing every 30 to 40 hours. A complete set of the 24 manganese steel hammers costs approximately $900, or $30/hour of P-500 operating time—if only 30 hours of hammer life are obtained. The hammers require 2 to 3 hours to change, even with the hatch opening that is now above the rotor.

The P-500 and other mobile hammermills are available from Pettibone Road Machinery Division, P. O. Box 4389, Ft. Worth, TX 76106. The suggested retail price for the P-500, as of January 1979, is approximately $55,000. The Iowa Manufacturing Company, Cedar Rapids, Iowa, plans to offer a Cedarapids self-propelled mobile hammermill by 1980, and the CMI Corporation, Oklahoma City, Okla., is also thinking of possibly producing such a unit.

Applications

The most obvious application for a mobile hammermill is to reduce the oversize material that accumulates along the roadways and fills the adjoining ditches. The oversize material is simply windrowed onto the roadway, is reduced by the towed hammermill, and is then incorporated into the running surface.

Another application for a hammermill is to reduce oversize material protruding from the road surface. For this application, the road surface must be scarified to remove the embedded material, which may require a crawler tractor with rippers. After this material is windrowed and processed by the hammermill, the processed material is bladed over the road surface. Thus, the oversize material is used in place and is not wasted.

Other applications include reclamation of asphalt roads and reduction of excavated oversize material encountered during road construction. Inplace reduction, to form either a base course or surface course, would utilize the existing material and reduce the need for expensive imported aggregate.

Roadbed Preparation

In most cases there is not enough oversize material scattered along roadways in the ditches to provide an adequate layer of aggregate. With the addition of oversize material embedded in the roadway there is usually enough material for a 3 to 4 in (7.6 to 10.2 cm) overlay.

First the roadway is usually scarified to a depth of 6 in (15.2 cm), which loosens all but the largest rocks—these have to be blasted or disposed of by other means. In most cases, a grader with ripper teeth is adequate, but for extreme cases a crawler tractor is required to scarify material adequately. The scarified material, along with the material pulled in from the ditches and roadsides, is formed into a windrow (figs. 4 and 5).

Figure 4. Roadbed being ripped by crawler tractor.

To obtain the most satisfactory results, the windrow size should be 1½ ft high by 3 ft wide (0.46 by 0.91 m). Although the P-500 has a clearance of 1½ ft (0.46 m) and a width of 5 ft (1.5 m) and can accommodate a larger windrow, this appears to be the optimum size. Also, hammer wear is more uniform when the optimum windrow size is used.

Figure 5. Windrow being prepared by motor grader.

Water

In most cases, water should be added to the windrow just prior to processing. There are several benefits to this: greater operator convenience and safety (primarily since there will be less dust), increased hammer life, and improved compaction of the finished aggregate. Generally, 2 to 3 gal of water per cu yd (5.8 to 8.7 l/m^3) of material is adequate to obtain the first two benefits (fig. 6).

Figure 6. Watering of windrow by water truck.

Travel Speed

The P-500 is usually towed over the windrow by a Caterpillar D-6 or equivalent, but any piece of equipment with at least 18 in (45.7 cm) of ground clearance, slow-speed capabilities, and adequate horsepower may be used. The travel speed is usually the maximum that will allow the engine driving the P-500 to operate at the governed speed. This normally provides the most adequate results, but a finer gradation may be obtained by reducing the travel speed. Travel speed normally is in the range of 25 to 50 fpm (7.6 to 15.2 m/min) for hard rock and 50 to 70 fpm (15.2 to 21.3 m/min) for cinder material (fig. 7).

Figure 7. P-500 being towed over windrow by crawler tractor.

PRODUCTION CAPABILITIES

Most of the use by SDEDC of the P-500 was during short-term demonstration, test, and evaluation programs conducted over the years on various Forests in all the western Regions with different operating personnel, for the most part, at each site. Data obtained at the many sites show that the production rate of the P-500 is affected primarily by material

Figure 8. Roadway before being processed by hammermill.

Figure 9. Roadway after being processed by hammermill.

gradation, material classification, windrow size, hammer length, and the desired finished product (figs. 8 and 9).

During a 2-week test on the Deschutes and Malheur National Forests in the Pacific Northwest Region, typical production rates were obtained and are discussed here. Material encountered ranged from andesite to cinders, with the bulk of the data being obtained from alluvial material—"river rock," which includes diorite, granite, basalt, breccia, andesite, and rhyolite.

Material Gradation

The size of the material is the most important factor pertaining to the production rate. The production rate is noticeably reduced from the average when large material (12 to 18 in, or 30.5 to 45.7 cm) comprises over 25 percent of the windrow volume. This is true since a second processing may be required to reduce the material to less than 3 in (75 mm). Details on gradation for each material type that was encountered are in the "Material Gradations" section that follows.

Material Classification

The physical structure of the material has an effect on the production rate. Argillite, a very brittle and slately material, tends to break easily and shatters into many small pieces. Basalt and andesite, although having a similar loss in the Los Angeles abrasion test (referred to as "LAR") as argillite, do not generally have a preferential cleavage in larger rocks (3+ in, or 75+ mm) and are more resilient. Thus, they do not fracture and break down in size as easily as argillite and provide a smaller percentage of 4 to 5 in (100 to 125 mm) material. Volcanic cinder, on the other hand, is a very poorly structured material that tends to break down very easily and provides a high production rate.

Windrow Size

The windrow size should be kept as near optimum—1½ by 3 ft, or 0.46 by 0.91 m—as possible. With windrows smaller than those in the optimum range, there isn't enough material to hold oversize rocks in place for the hammers to strike; larger windrows are beyond the horsepower required for effective hammer impact, and the material receives only a violent mixing from the hammer's blows. Figure 10 shows the tractor/hammermill combination straddling a proper windrow for effective size reduction.

Figure 10. Crawler tractor and hammermill straddling an optimum-size windrow.

Hammer Length

As the length of the hammers decreases due to wear, so does their weight and consequently their impact energy. When they are reduced to a length of only 8 in (20.3 cm), they have lost most of their effectiveness (fig. 11).

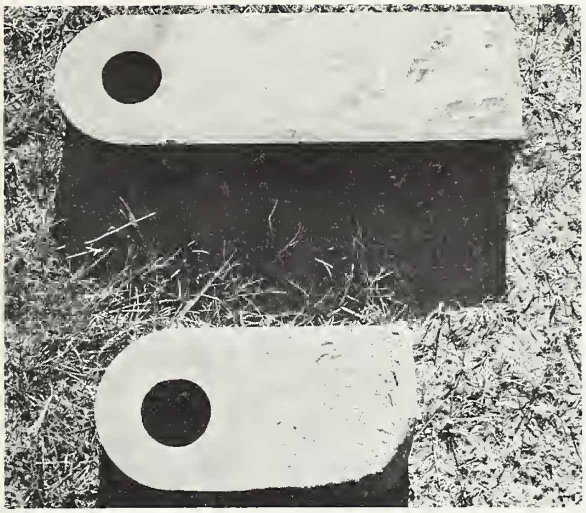

Figure 11. New and used hammers.

Desired Product

The most important effect on production can easily be what is considered the desired product. Do not expect the P-500 to produce a specific material gradation; for example, a grading G (a 1½ in, or 37.5 mm, minus, etc.) Do expect the P-500, under normal conditions, to process material so that over 95 percent will pass a 3-in (75-mm) screen after one processing. In some cases, two processings may be needed–see the section that follows.

MATERIAL GRADATIONS

The tables and graphs in this section present the gradations prior to, and also the results after, processing with the P-500. In almost all cases, even where rock up to 18 in (45.7 cm) was encountered, 100 percent of the material passed through the 3-in (75-mm) screen. In the few instances where some material greater than 3 in (75 mm) remained after one processing, a second processing reduced this material to less than 3 in (75 mm). In fact, after the second processing, 90 to 95 percent of the material passed through the 1½-in (37.5-mm) screen.

Throughout the material-sampling process, only material less than 5 in (125 mm) was taken to the laboratory for gradation analysis. The percentage of material greater than 5 in (125 mm) was estimated by the material engineer and then incorporated into the gradation calculations.

Argillite

Argillite is a sedimentary, shaley rock metamorphized to hard, platey shale or slate-like material. This rock type is medium hard with an LAR loss of 17 and definite planes of weakness and fracture. Consequently, this material breaks rather easily under high impact. The average processing rate for argillite was approximately 125 cu yd/hr (95.6 m^3/h).

Table 1. Percentage by weight of argillite passing through sieves

Sieve designation		Percent passing	
Standard (mm)	Alternate (in)	Before processing	After processing
457	18	100	100
125	5	80	100
75	3	69	100
50	2	61	99
37.5	1½	53	95
25.0	1	44	87
19.0	¾	38	76
12.5	½	30	62
9.5	3/8	26	54
4.75	No. 4 1/	20	39

1/ Nominal opening, 0.187 in.

Table 1 presents the gradation before and after processing; figure 12 illustrates the same data in graphical form for the argillite that was encountered.

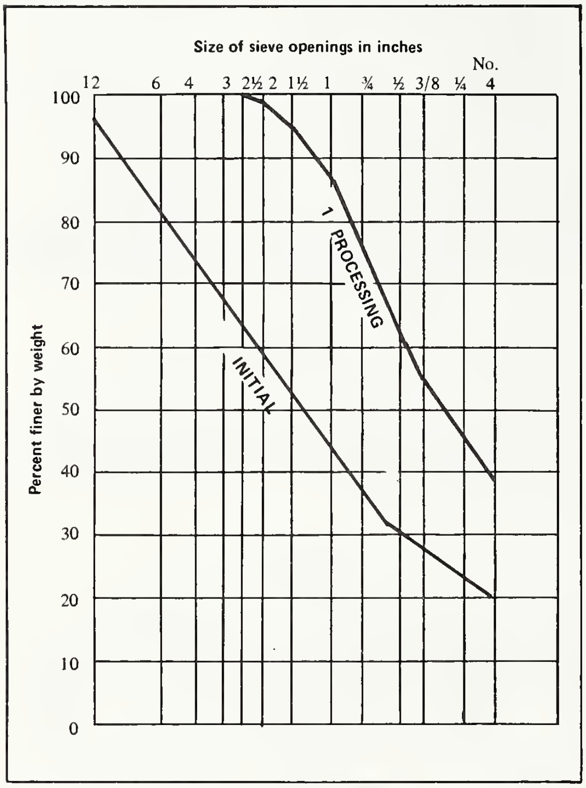

Figure 12. Argillite gradations.

Basalt and Andesite

The basalt and andesite were encountered with numerous pieces of basalt scoria and agglomerate. The pieces were angular and appeared to be derived

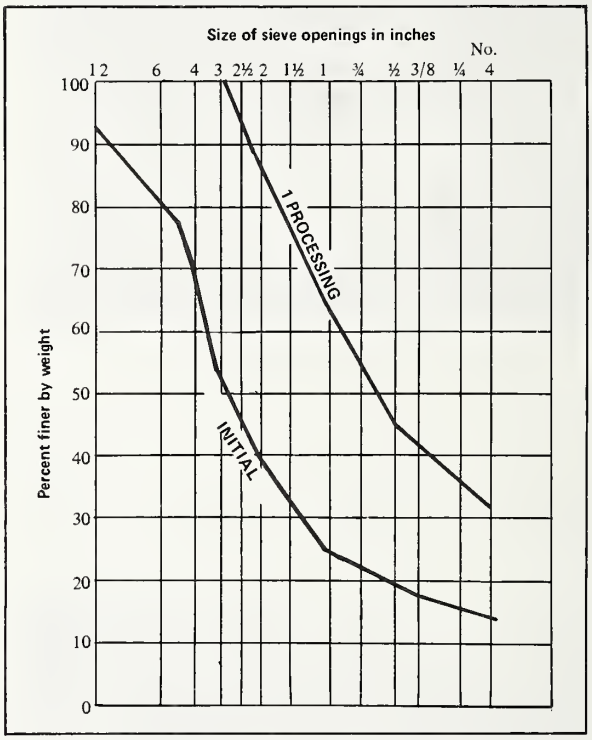

Figure 13. Basalt and andesite gradations.

Table 2. Percentage by weight of basalt and andesite passing through sieves

Sieve designation		Percent passing	
Standard (mm)	Alternate (in)	Before processing	After processing
457	18	100	100
125	5	72	100
75	3	50	100
50	2	37	86
37.5	1½	32	77
25.0	1	24	63
19.0	¾	22	54
12.5	½	19	45
9.5	3/8	18	41
4.75	No. 4 1/	15	32

1/ Nominal opening, 0.187 in.

from the breakdown of the native agglomerate. This was the toughest material of all those processed during the tests. The P-500 production rate averaged only 100 cu yd/hr (76.5 m^3/h).

Table 2 and figure 13 present the gradations for the basalt and andesite.

Alluvial

The alluvial ("river rock"), mostly volcanic in origin, was well-rounded and included diorite, granite, basalt, breccia, andesite, and rhyolite. This material had the highest percentage of oversize material. Approximately 55 percent was greater than 3 in (75 mm); this required that the rock be processed twice to meet the 3-in (75-mm) size requirement.

The average processing rate for the first processing with the P-500 was 150 cu yd/hr (114.7 m^3/h); the average rate for the second processing was 235 cu yd/hr (179.7 m^3/h), for an overall rate of 90 cu yd/hr (68.8 m^3/h). The second processing may not have been necessary had the initial processing speed been reduced. However, the governed rpm speed of the P-500 was used as the controlling factor.

Table 3 and figure 14 present the gradations for the alluvial.

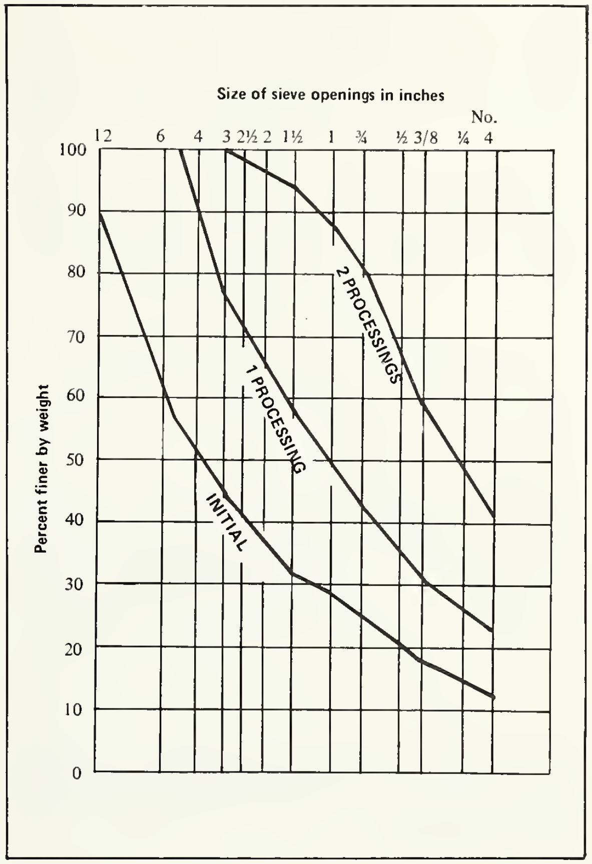

Figure 14. Alluvial gradations.

Table 3. Percentage by weight of alluvial passing through sieves

Sieve designation		Percent passing		
Standard (mm)	Alternate (in)	Before processing	After 1 processing	After 2 processings
457	18	100	100	100
125	5	57	100	100
75	3	45	77	100
50	2	36	66	96
37.5	1½	32	59	94
25.0	1	29	50	88
19.0	¾	25	43	82
12.5	½	21	36	68
9.5	3/8	18	31	59
4.75	No. 4 1/	13	23	41

1/ Nominal opening, 0.187 in.

Volcanic Cinder

About 300 cu yd (274.2 m^3) of volcanic cinder was hauled onto a road section for this test, since large cinders (6+ in, or 15.2+ cm) were not found along the roadway. An estimated 20 percent of this material was greater than 3 in (75 mm). In fact, processing time was increased because of difficulties in getting the crawler tractor to clear the large material. The processing rate for the cinders was in excess of 180 cu yd/hr (137.6 m^3/h).

During this test an occasional large "clinker" 10 to 24 in (25.4 to 61.0 cm) would be encountered that did not break easily. After the first processing by the P-500 a few pieces as large as 5 in (125 mm) would be left. A second processing was made in an effort to reduce these up to 5 in (125 mm) clinkers to 3 in (75 mm); however, the cinders were pulverized to ½ in (12.5 mm) minus, or less.

Table 4 and figure 15 present the gradations for the volcanic cinder.

Figure 16 presents the processing rates actually experienced for the four material classifications, the LAR for each, and the size of rock that resulted from the P-500 processing.

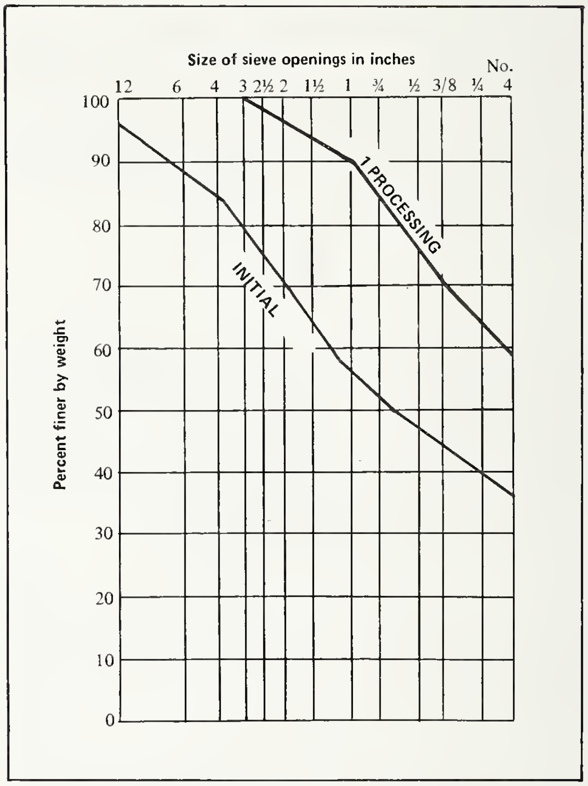

Figure 15. Volcanic cinder gradations.

PRODUCTION COSTS

SDEDC's experience with the P-500 showed that an average production cost of approximately \$2.00/cu yd (\$2.62/m^3) is incurred. This includes a motor grader, crawler tractor (a Caterpillar D-6 or equivalent) to pull the P-500, the P-500 hammermill, water truck, and four operators. Several factors influence the costs that are actually incurred—the efficiency of the overall operation, amount of scarification and minor reconstruction needed, hammer wear experienced, and distance to a water source.

Table 4. Percentage by weight of volcanic cinder passing through sieves

Sieve designation		Percent passing	
Standard (mm)	Alternate (in)	Before processing	After processing
457	18	99	
75	3	79	100
25.0	1	56	90
9.5	3/8	44	71
4.75	No. 4 1/	36	59

1/ Nominal opening, 0.187 in.

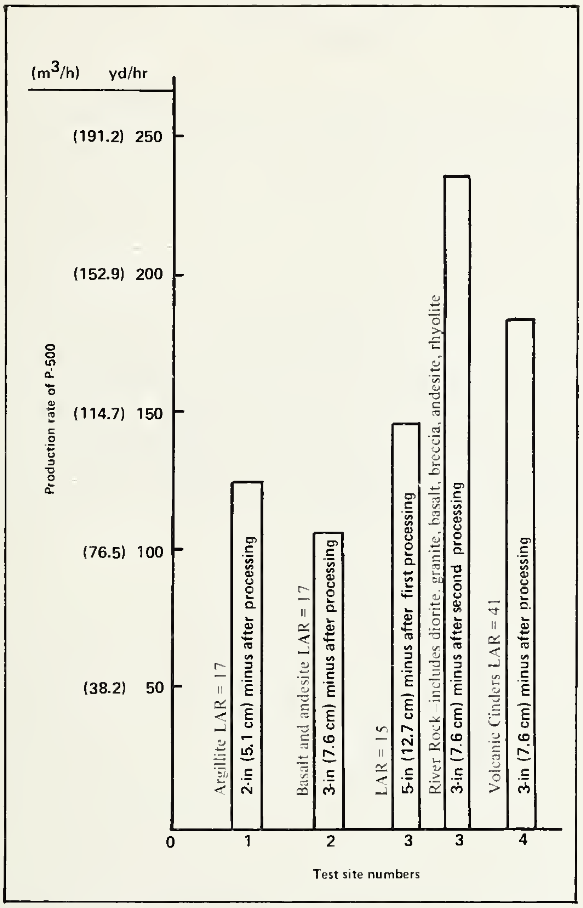

Figure 16. Production rates by material classifications.

When scarification with a grader is required to remove oversize material embedded in the roadway, a rule of thumb is that 3 hours of grader time will be spent for each hour of P-500 operation. The grader must scarify, prepare the windrow, and then spread the processed rock. In these cases, efficiency may be significantly improved by either having two graders, or having the pulling tractor help with the ripping while the hammermill is idle part of the day.

The Rocky Mountain Region reports an average cost of \$3,000/mi (\$1,865/km) over the past several years, using a small mobile hammermill—the Browning Manufacturing Company's Rock Buster model RB-4, which was last produced in 1959. This cost includes minor reconstruction, addition of culverts, scarification, and the processing of 4 in (100 mm) of aggregate over the roadway. Thus, using the production cost of \$2.00/cu yd (\$2.62/m^3) on a typical 14-ft (4.3-m) road, the cost of the aggregate per mile would be approximately \$1,900—which is not out of line with what the Rocky Mountain Region is experiencing with a hammermill that is less efficient than the P-500.

In the Pacific Northwest Region, the P-500 in the fall of 1977 reduced asphalt chunks during reclamation of an asphalt road on the Malheur National Forest. The ripping and P-500 processing cost was \$1.00/cu yd (\$1.31/m^3).

HAMMERMILL MODIFICATIONS

Completed

Several modifications, suggested by SDEDC engineers and technicians, have been made to the P-500. These changes have greatly improved its operating efficiency and safety and have been incorporated into mobile hammermills presently being offered by Pettibone.

Hammers and Pins

The greatest need for improvement that was uncovered was extension of the hammer and pin life of the hammermills. Changes in alloys and steel compositions used in their fabrication increased hammer life from 8 to 40 hours. Also, pins now need only be changed with every other hammer change—saving approximately \$50 for every 80 hours of use.

Access Hatch

An access hatch was installed above the rotor, which contains the hammers and pins. This provided a safer and more convenient method for changing the hammers and pins than from the bottom, as was previously the case. Installation of the access hatch above the rotor speeds up hammer changing by 30 percent.

Operational Controls

At the conclusion of SDEDC testing in the Pacific Northwest Region, operational controls were installed on the towing tractor by personnel at the Malheur National Forest. This eliminated the need for a P-500 operator, paring down operating costs.

Recommended

SDEDC personnel feel the following changes to mobile hammermills would be beneficial:

- Making the machines self-propelled would reduce their costs approximately 30 percent by eliminating the necessity of a towing tractor.

- Continuing efforts to extend hammer and pin life through design improvements and refinements in alloy composition.

- Installing a water tank on hammermills, especially in arid areas, would greatly improve efficiency and reduce operating costs.

CONCLUSIONS

The P-500 is an excellent road maintenance tool because it effectively and efficiently reduced unwanted oversize material in place into usable material. The hammermill performs most effectively when reducing material to a 3-in (75-mm) size gradation.

The P-500 normally reduces the oversize material so that 90 percent passes through a 3-in (75-mm) screen after one processing. Normally, two processings insure that 100 percent of the material passes through the 3-in (75-mm) screen. However, finer gradations may not be most efficiently obtained with the P-500 and, if this is the goal, other possible reduction methods should be considered.

EQUIPMENT DEVELOPMENT AND TEST

The Forest Service's Equipment Development and Test (ED&T) program, conducted by two Equipment Development Centers (San Dimas, Calif., and Missoula, Mont.), provides systematic application of scientific knowledge to create new or substantially improved equipment, systems, materials, processes, techniques, and procedures that meet the objectives of advanced forest management and utilization in the United States. The ED&T effort, featuring Mechanical Engineering activities, encompasses projects in forest engineering, aviation and fire management, recreation, timber, range, wildlife, occupational safety and health, forest insect and disease, and forest residues to enable forest work to be performed more efficiently, at less cost, with minimum hazard.

As needs for field development services are identified and defined, the Centers determine if already available commercial products are suitable as is or if they require modifications necessitated by the forest environment. On the other hand, sometimes needs can only be met by the Centers taking advantage of the latest technology to create new concepts through a step-by-step product development program. These developments are typically achieved by active ED&T involvement with disciplines found throughout the Forest Service. The new equipment is field tested and demonstrated and user feedback is obtained to evaluate results. The role of the Centers is not considered complete until project output is implemented in the field.

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